View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Elsevier - Publisher Connector

Eur J Vasc Endovasc Surg **28**, 534–542 (2004)
doi:10.1016/j.ejvs.2004.08.005, available online at http://www.sciencedirect.com on SCIENCE DIRECT

Effect of Suprarenal Stent Struts on the Renal Artery with Ostial Calcification Observed on CT Virtual Intravascular Endoscopy

Z. Sun[1]* and H. Zheng[2]

[1]*School of Applied Medical Sciences and Sports Studies, and* [2]*School of Computing and Mathematics, University of Ulster, Newtownabbey, Northern Ireland, UK*

Objectives. *The behaviour of stent struts crossing the renal ostia and their effect on renal ostia configuration is not well understood. The study aims to investigate whether suprarenal stent struts affect the morphological change of the renal artery with ostial calcification observed on CT virtual intravascular endoscopy.*
Methods. *Nine patients with abdominal aortic aneurysms undergoing suprarenal fixation of stent grafts were included in the study. All patients received a Zenith endovascular graft with uncovered suprarenal components placed above the renal arteries. Renal ostial calcification and configuration of stent wires crossing the renal ostium were characterized in each patient and maximal transverse and longitudinal diameters of the renal ostia were measured on virtual endoscopy pre- and post-stent grafting.*
Results. *There were altogether 17 renal ostia assessed with one patient having atrophic left kidney and no renal ostium being observed. Ostial calcification was found in five of the left renal ostia and five of the right renal ostia with one patient having bilateral ostial calcification. There was no significant difference between the renal ostial diameters measured pre- and post-stent grafting ($p > 0.05$). Suprarenal stent struts were found to cross the renal ostia in various configurations observed on virtual endoscopy. All of the renal arteries were patent on follow-up CT scans after suprarenal fixation without stenosis or occlusion being observed. One patient with atrophic left renal artery developed renal failure following suprarenal stent grafting and received renal dialysis, while in the remaining cases median serum creatinine level did not change significantly.*
Conclusions. *Suprarenal stent struts did not significantly affect the renal ostia with ostial calcification in terms of the diameter measurements and renal function. Further studies deserve to investigate the long-term effect of stent struts on the renal artery in terms of cross-sectional area reduction caused by stent wires and ostial calcification.*

Keywords: Renal ostium; Stent graft; Computed tomography; Calcification; Virtual endoscopy.

Introduction

Endovascular stent grafting of abdominal aortic aneurysm (AAA) has entered clinical practice for more than a decade and clinical investigations have shown potential future for the technique.[1–3] Endovascular repair was found to be less invasive and an effective alternative to conventional surgical repair of AAA, especially in those high-risk patients. With experience gathered, it has been found that nearly 30–40% of patients with AAA were unsuitable for the common treatment of infrarenal stent grafting due to suboptimal aneurysm necks. This is either due to inadequate length of the aneurysm neck (less than 15 mm), or widened aneurysm neck (wider than 28 mm) or angulated aneurysm neck (angle greater than 60°), or poor quality of aneurysm neck (mural thrombus or atheromatous or extensive calcification).[4–6] Methods of dealing with these difficulties have been investigated and one of the commonly used method is suprarenal fixation which is designed to place an uncovered suprarenal component over the renal artery ostium to improve the proximal fixation of stent graft and reduce the incidence of proximal endoleaks and migration in patients with short and difficult aneurysm necks.[7,8] However, the long-term effect of suprarenal fixation of stent grafts is still unknown. One of the main concerns is the interference of stent struts with the renal blood flow, although short

* Corresponding author. Dr Zhonghua Sun, Room 15J 13, School of Applied Medical Sciences and Sports Studies, University of Ulster, Shore Road, Newtownabbey BT37 0QB, Northern Ireland, UK
E-mail address: zh.sun@ulster.ac.uk (Z. Sun).

1078–5884/000534 + 09 $35.00/0 © 2004 Elsevier Ltd. All rights reserved.

to medium-term reports did not show any significant renal dysfunction.[8–12] Another possible effect of stent struts on the renal arteries is the morphological interference of renal ostia after the suprarenal fixation. This seems particularly important in patients with renal ostial calcification as stent struts were reported to cover some areas of the renal ostia.[9,13,14] The patency of stent-covered renal arteries is of utmost importance following suprarenal fixation and helical CT angiography (CTA) is the preferred method to follow-up patients treated with aortic stent grafting.[15,16] CTA-generated virtual intravascular endoscopy (VIE) is a recently developed technique and capable of providing intraluminal views of both normal anatomic structures (the aorta, its branches and stent struts), configuration between stent struts and aortic ostium and pathological changes such as intraluminal calcification.[17–19] Virtual endoscopic imaging allows the precise position of stent struts to be assessed and this has been previously validated using a stent graft phantom.[19] Moreover, VIE was recently reported to be a valuable technique in the visualisation of the encroachment of stent struts to the renal ostium when compared to axial CT and other 3D post-processing methods in a cohort of patients with AAA treated with suprarenal stent grafts.[17] However, interference of morphological configuration to the renal ostium by suprarenal stent struts has not been addressed in the study. To our knowledge, there has been no report regarding the effect of stent struts on the renal ostium in terms of morphological change, particularly in those patients with ostial calcification. The calcified plaque may be displaced by the presence of stent wires and subsequent renal perfusion or renal blood flow will be affected, although this has never been investigated before. Therefore, the purpose of this study was to investigate whether the suprarenal stent struts would have any effect on the morphological change of renal ostium, especially in those with ostial calcification based on our preliminary experience of VIE findings.

Materials and Methods

Of 47 patients with AAA undergoing suprarenal fixation of stent grafts, nine were found to have calcification in the renal ostia and, therefore, included in the study. There were seven men and two women with age ranging from 76 to 83 years (mean age 78 years). All patients were treated with a Zenith™/AAA (Cook Europe, Denmark) stent graft with uncovered suprarenal component placed above the renal arteries for proximal fixation. All patients were given an intravenous contrast enhancement with a total volume of 100 ml administered at an injection rate of 2 ml/s and a scan delay of 30 s. Helical CTA was performed pre- and post-stent grafting at a single slice CT scanner (Philips AV-E1) with the scanning protocol of collimation 5 mm, pitch 1.0 and reconstruction interval of 2 mm. Post-stent grafting CTA datasets were acquired within 1 week following stent graft implantation. Virtual endoscopic images of the renal ostium and aortic stent struts were post-processed in a workstation equipped with a commercial software Analyze V 4.0 (www.analyzedirect.com, Mayo Clinic USA). Generation of VIE images was determined by a CT number thresholding.[20] A CT number range applied to generate optimal VIE images with fewer artefacts was identified by measuring the region of interest in the level of renal arteries (Fig. 1). The threshold range was measured in each patient as the degree of contrast enhancement was different individually.

Calcification around the renal ostium was characterised into the following types as shown in Fig. 2(a)–(e): focal calcification within the renal ostium (A), circular calcification outside the renal ostium (outer circular—B), circular calcification inside the renal ostium (inner circular—C), semi-circular calcification outside the renal ostium (D), semicircular calcification inside the renal ostium (E). Fig. 2(f) showed that the red circle indicated the outer edge of the renal ostium and the short straight line demonstrated the area of renal ostium covered by the calcification. Configuration of encroachment to the renal ostium by a stent wire was characterised into the following types on the basis of previous experiences:[14,20] a stent wire placed across the centre of the ostium (A), an off-centre wire positioned at one quarter of the ostial diameter (B), a V-shaped wire with its vertex at the centre (C) and 2 stent wires spaced at one third of the ostial diameter (D).

Maximal transverse and longitudinal diameters of the renal ostium were measured on VIE images. Comparison was performed to determine if there is any significant difference between diameters measured pre- and post-stent grafting in terms of the morphological change. 3D relationship of stent struts relative to the renal ostia was also assessed on VIE, which includes the number and configuration of stent wires crossing the renal ostia. Renal function was assessed using serum creatinine levels, which were measured pre-operatively and prior to discharge. A Student T test was used to analyse the results and a p value less than 0.05 was considered statistically significant difference.

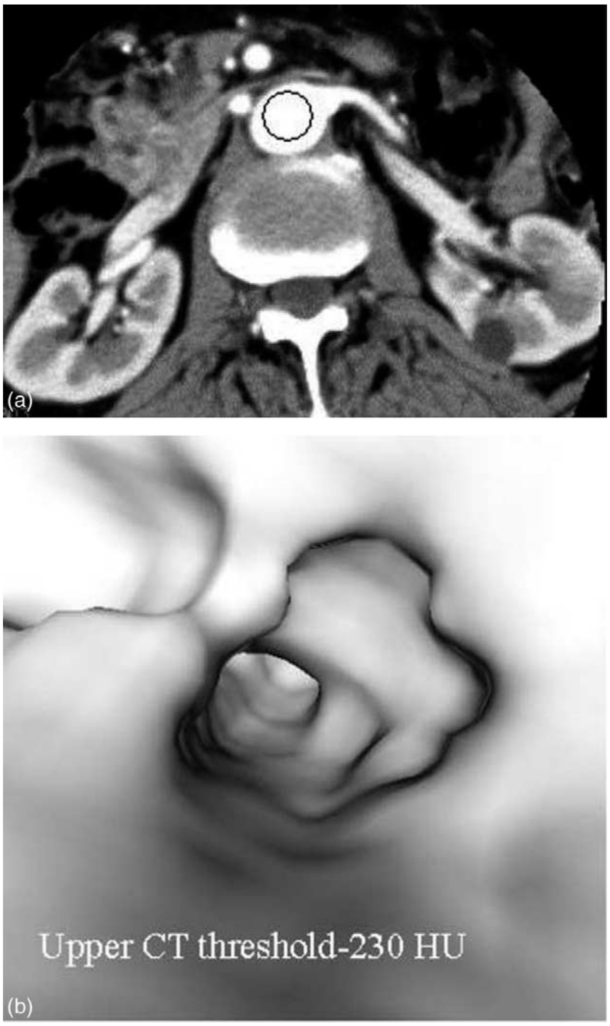

Fig. 1. A threshold range was determined by measuring the region of interest in the level of renal artery (a) and applied to remove the contrast-enhanced blood from the aorta. A virtual endoscopic image (b) of the left renal ostium was clearly visualised after applying the threshold (230 HU).

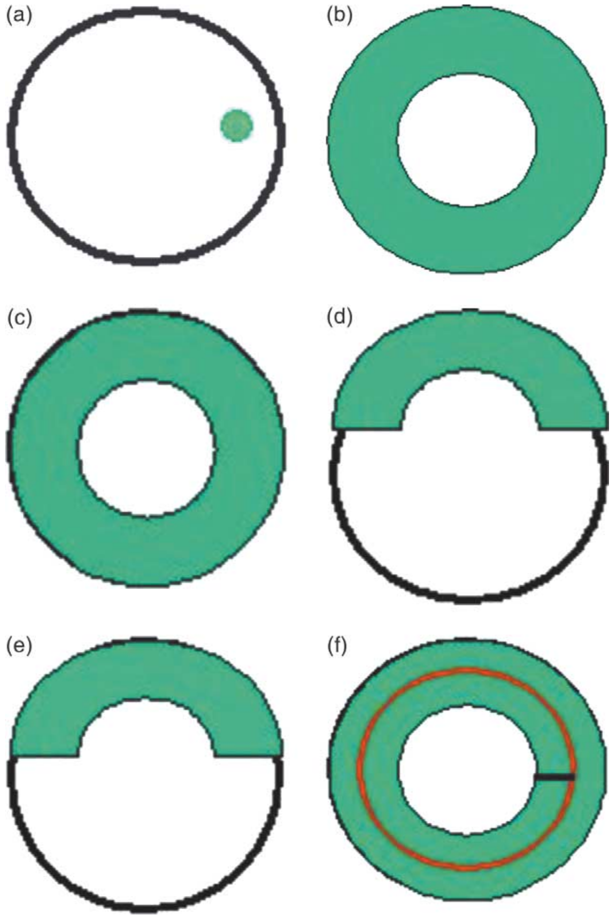

Fig. 2. Characterisation of calcification in the renal ostium. (a)–(e) Show these different types of calcification in the following order: focal calcification within the renal ostium (a); outer circular calcification indicates that calcification locates outside of the ostium (b); while inner circular calcification indicates calcification to be inside of the ostium (c); semicircular calcification outside the renal ostium but partially covers the ostium (d); semicircular calcification within the renal ostium (e); (f) shows that measurement of the renal ostial diameter is underestimated due to the overlapping of calcification in type C and E.

Results

VIE images of the renal ostia and stent struts were successfully generated in all patients. There were altogether 17 renal ostia assessed in the study. One patient had an atrophic left kidney and no filling of the left renal artery was observed. Calcification was found in five of the left renal ostia and five of the right renal ostia. Calcification was present in bilateral renal ostia in one patient. Calcification was not found to be present in seven renal ostia. The median CT attenuation of the calcified plaque measured 471 HU (range: 303–1079 HU). The range, median CT attenuation and threshold range selected for generation of VIE images were shown in Table 1. It was found that the lowest CT attenuation of calcified plaque is greater than the highest threshold value applied to generate VIE images. Therefore, after applying the threshold calcified plaques were removed from the aorta together with contrast-enhanced blood and demonstrated as signs of protrusion in the aortic wall. Renal ostial calcification was visualised on VIE as various types, which was shown in Table 2. Type A–E calcification was found in 3/10, 2/10, 3/10, 1/10 and 1/10, respectively, (Fig. 3). For the type B and D calcification as shown in Fig. 2(f), part of the renal ostium was covered by the presence of calcification resulting in underestimation of the ostial diameter, which was noticed in three of 10 renal ostia. Table 2 also showed

Table 1. Median, range of CT attenuation and threshold selected for generation of VIE images in both pre- and post-stent grafting

Patient no.	Pre-stent grafting		Post-stent grafting	
	CT attenuation (HU)	Threshold (HU)	CT attenuation (HU)	Threshold (HU)
1	190	120	170	75
2	198	133	203	164
3	203	90	178	88
4	203	90	220	103
5	187	120	219	110
6	193	100	163	90
7	217	187	206	110
8	232	116	228	100
9	237	120	115	115
Median	203	120	189	103

measurements of the renal ostial diameters in transverse and longitudinal directions, pre- and post-stent grafting. There was no significant difference between diameters of the renal ostia with and without calcification measured on VIE pre- and post-stent grafting ($p>0.05$). However, morphological change of the renal ostium was found to be more apparent in those without ostial calcification than those with calcification due to the presence of suprarenal stent struts (Fig. 4).

The number and configuration of stent struts crossing the renal ostia was visualised clearly on VIE images. The number of stent struts ranged from one wire to two wires and configuration of the encroachment was variable, which was shown in Table 2. There were about half (8/17) of the renal ostia crossed by two wires. It was also noticed that the stent struts were overestimated on VIE images and diameters ranged from 1 to 2 mm, while the real size of a stent strut is 0.4 mm in diameter. Therefore, the accurate coverage of stent struts of the renal ostia was not evaluated in the study, although it seems that more than 50% of the renal ostia was covered by stent struts in most patients (Fig. 5).

All of the renal ostia remained patent on both axial CT and VIE images following suprarenal fixation and no stenosis or occlusion was observed. In the patient with atrophic left renal artery, serum creatinine level increased from pre-operative 188 μmol/l to post-operative 249 μmol/l and the patient received renal dialysis.

In the remaining patients, the median pre- and post-operative serum creatinine level was 89 g μmol/l (range: 73–131), 87 μmol/l (range: 79–129), respectively, and it did not change significantly following suprarenal stent grafting ($p>0.05$).

Discussion

Suprarenal or transrenal fixation of aortic stent graft is well established as a safe and effective means of treating

Table 2. Comparison of diameters of the renal ostia measured pre- and post-stent grafting and the number of stent struts crossing the renal ostia and type of calcification

Patients no.	Diameters of the left renal ostium (mm)		Diameters of the right renal ostium (mm)		No. and type of stent wires crossing the renal ostium		Characterisation of calcification
	Pre-stent grafting	Post-stent grafting	Pre-stent grafting	Post-stent grafting	Left renal ostium	Right renal ostium	
1	$\underline{5\times6}$	$\underline{6\times6}$	$\underline{6\times9}$	$\underline{7\times9}$	One (A)	Two (D)	B, C
2	4×5	5×7	$\underline{5\times7}$	$\underline{7\times7}$	Two (D)	One (A)	A
3	$\underline{9\times8}$	$\underline{8\times8}$	7×9	7×10	Two (D)	Two (D)	D
4	–	–	$\underline{5\times8}$	$\underline{5\times8}$	–	Two (C)	C
5	6×7	7×6	$\underline{9\times6}$	$\underline{8\times7}$	Two (D)	One (B)	A
6	$\underline{12\times9}$	$\underline{11\times9}$	11×6	11×5	One (B)	Two (D)	C
7	6×8	6×9	$\underline{7\times9}$	$\underline{7\times9}$	One (A)	One (B)	A
8	$\underline{6\times9}$	$\underline{6\times9}$	7×6	7×6	One (B)	Two (D)	B
9	$\underline{9\times9}$	$\underline{8\times9}$	8×9	8×10	One (B)	One (A)	E
Median	6×8	7×9	7×8	7×8			

The underlined measurements indicate the renal ostia with ostial calcification. Characterisation of calcification: A, focal; B, outer circular; C, inner circular; D, semi-circular outside the ostium; E, semicircular inside the ostium. Characterisation of stent wire relative to ostium: A, central stent wire; B, off-centre wire placed at one quarter of the ostium; C, V-shaped stent wire; D, 2 stent wires placed at one third of the ostium.

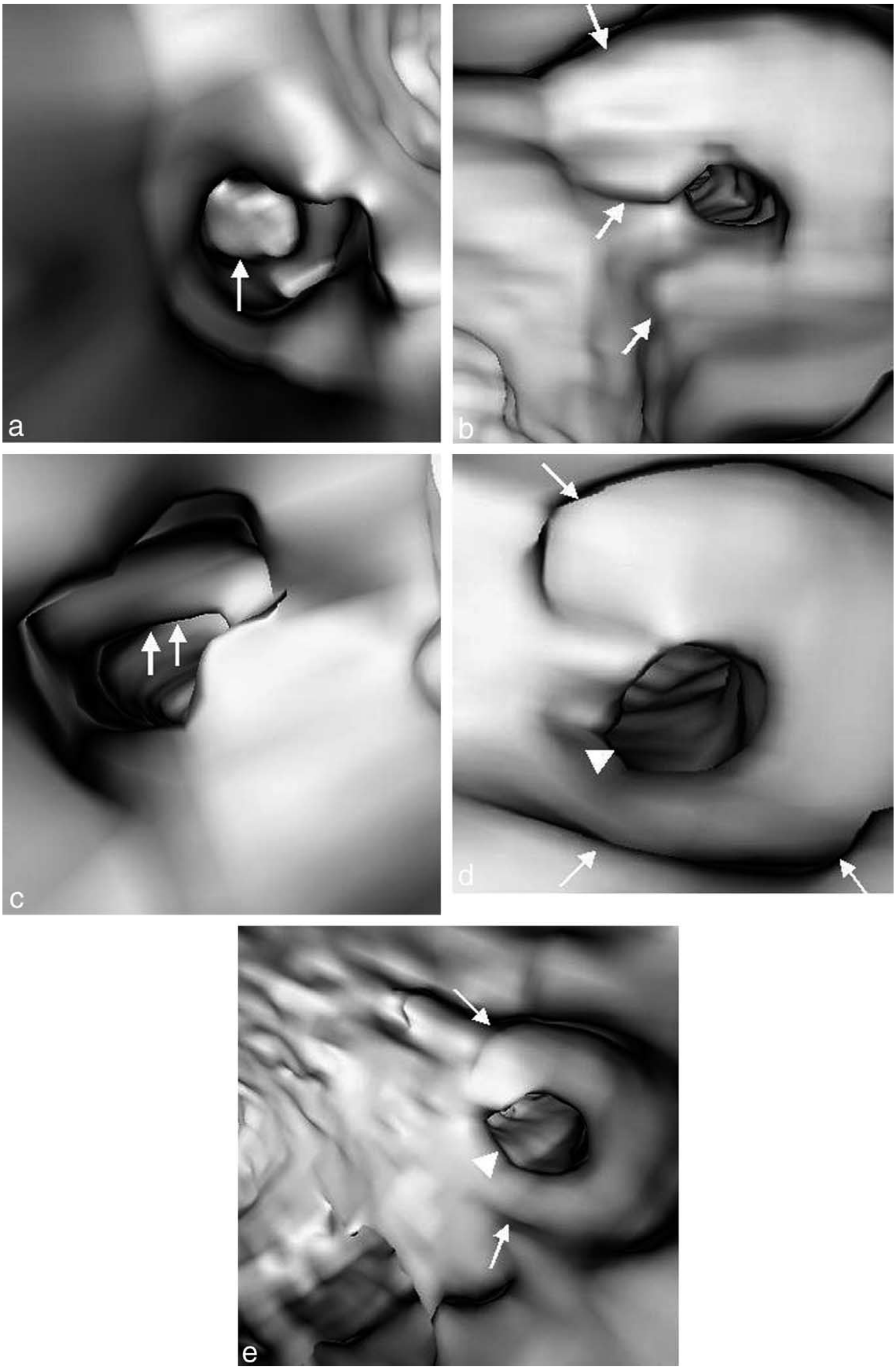

Fig. 3. Various types of calcification (a–e) in the renal ostium observed on VIE images. Arrows indicate the calcification, while arrowheads point to the renal ostia.

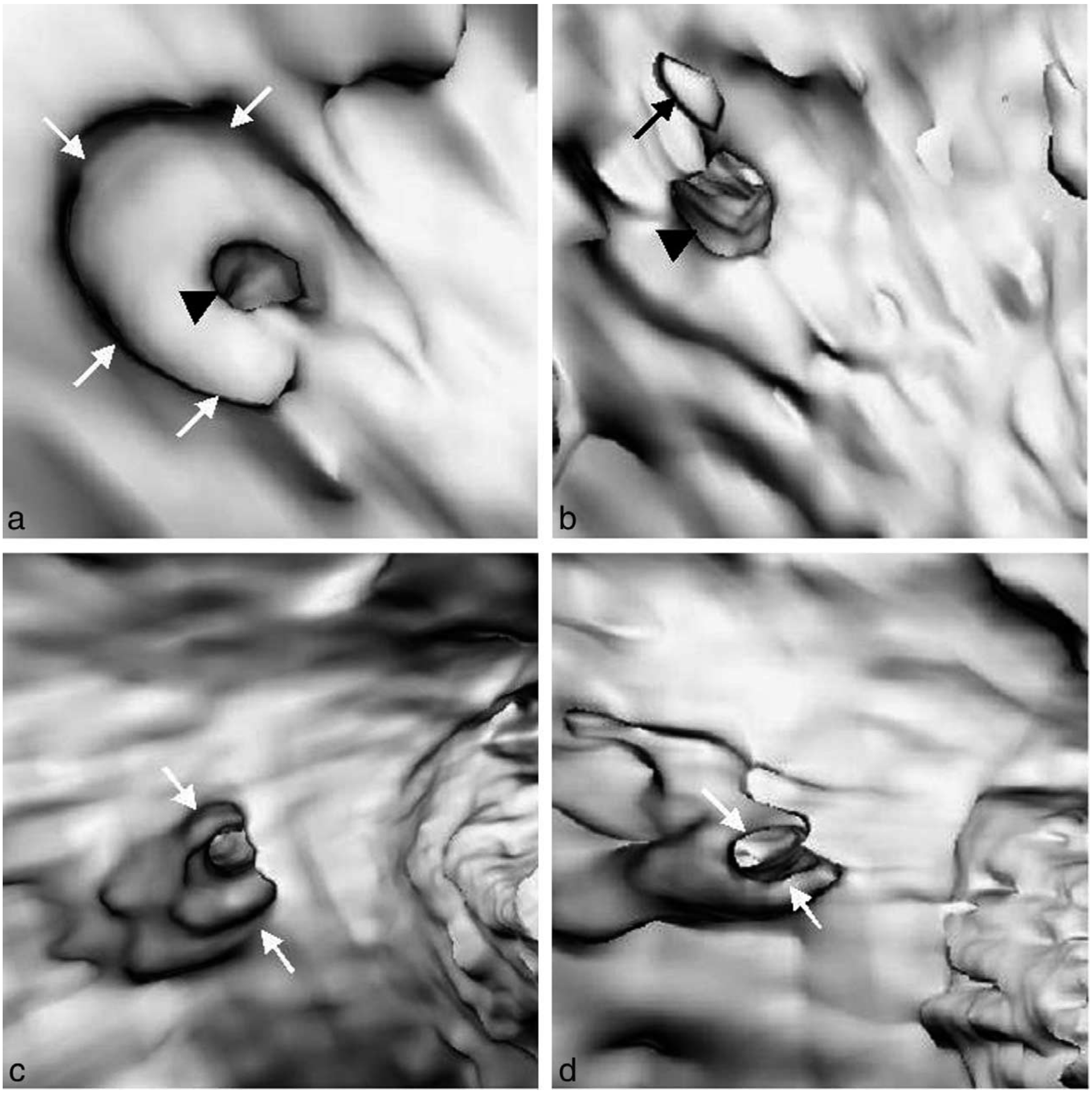

Fig. 4. The left renal ostium (arrowhead in a) pre-stent grafting remains the similar configuration following suprarenal fixation (arrowhead in b). Circular calcification (arrows in a) is noticed around the renal ostium. A floating shape artefact (arrowhead in b) is present near the renal ostium and caused by the inappropriate threshold selection. The right renal ostium without calcification (arrows in c) became distorted in configuration after suprarenal fixation (arrows in d) due to the presence of stent wires in front of the renal ostium.

patients with AAA and earlier studies support the renal safety of suprarenal stent graft fixation.[6–12,21–24] However, long-term effect of deployed uncovered stent on the renal artery ostia remains a major concern. This is especially apparent in patients with concomitant renal artery atherosclerotic disease because it is characterised by a natural history of progression to total occlusion.[25,26] Similarly, it is important to know whether the renal ostia with pre-existent calcification is affected following transrenal fixation as the management strategy will be changed if there is any interference. However, this was not found to result in significant decreased renal ostial diameter and renal dysfunction, according to our study. The incidence of renal failure following suprarenal fixation is poorly documented in the literature. Although it is unclear whether the renal failure occurred in one of our patients after suprarenal fixation was either due to the pre-existing renal dysfunction or as a result of

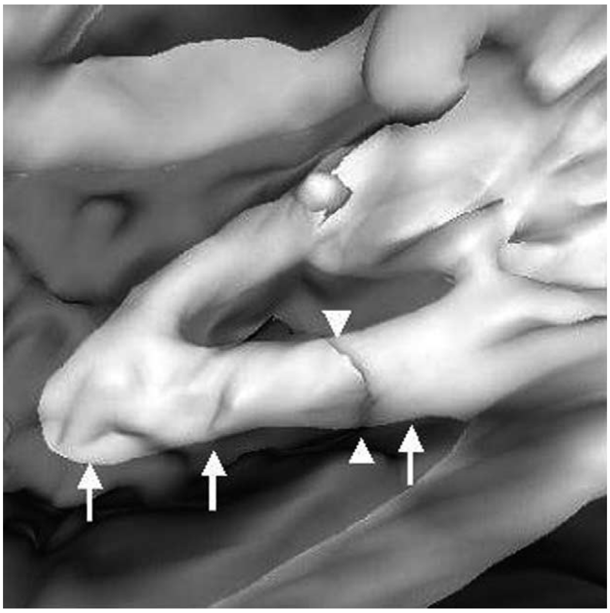

Fig. 5. Central stent wire crossing the right renal ostium was observed in an 83-year-old man with an infrarenal AAA. It was demonstrated that more than 50% of the renal ostium was covered by the stent wire due to the overestimated thickness of metal wire. Arrows indicate suprarenal stent struts (wires), while arrowheads point to the renal ostia.

the effect of suprarenal stent wires or calcification, our preliminary results should arise clinical awareness in patients with atherosclerotic disease such as renal ostial calcification. It is possible to physically displace plaque (especially type D and E) in the vicinity of the renal ostium during deployment of the suprarenal stent graft, supposedly that the stent wire was always deployed adjacent to the opening of the renal ostium. Although this was not observed in our study due to a small number of cases and no conclusion can be drawn, future studies in this area deserves to be investigated. VIE will be a valuable technique in this observation through visualising the change of configuration in both renal ostia and calcified plaque.

It is difficult to evaluate the morphological appearance and effect of stent struts on renal ostia on conventional axial CT and other 3D imaging methods.[18] This is especially apparent in post-stent grafting as high density metal wires will obscure the visualisation of pre-existent renal ostial calcification. Intravascular ultrasound was reported to be a reliable tool for intravascular visualisation when compared with angiography,[27] however, it is still an invasive and technically demanding method. The limitation was easily overcome by VIE as it allows non-invasive direct visualisation of intravascular views of the renal ostia, intraluminal calcification and stent wires from various angles. Moreover, the 3D relationship between stent struts and renal ostia was clearly demonstrated in our study.

Presence of stent wires in front of the renal ostium, especially 2-wire configuration has been investigated experimentally and reported to have the largest obstructive surface area.[14] The presence of ostial calcification will undoubtedly further reduce the cross-sectional area of the renal ostium, although it is difficult to measure the percentage of area reduction caused by the calcification. Despite a small number of cases were included in our study, our results showed that nearly half of the renal ostia were covered by two stent wires. Therefore, special attention should be paid to these patients while monitoring the renal blood flow or renal function. We consider that VIE findings presented in this study will aid vascular surgeons or interventional radiologists to accurately assess the effect of suprarenal fixation and therapeutic management.

Distortion of the renal ostium by the presence of a stent wire could occur following suprarenal fixation, although this has not been addressed before. One could imagine that those renal arteries with ostial calcification are less likely to be distorted by the stent wires than those without ostial calcification, as shown in our patient group (Fig. 4). Our study showed that renal ostia without calcification were more easily distorted than those with ostial calcification by the presence of stent wires, although the results were based on a short period of follow-up. Comparison of these two groups is currently under investigation in our institute over regular periods of follow-up.

One of the disadvantages of helical CTA in the imaging of stent grafts is the blurring effect that results in overestimation of the thickness of stent wires as displayed in both axial CT and VIE images according to recent studies.[18,28] However, measurements of the renal ostia diameter were not affected in our study as metal wires were removed after applying the appropriate threshold to only visualise the renal ostia on VIE. Therefore, we know only a small proportion of the renal ostium was covered in reality. Although diameters of the renal ostia were not found to change significantly in our study, nearly half of the renal ostial measurements were affected by the presence of adjacent calcification (type C or D). We consider that a more accurate method would be measuring the cross-sectional area reduction of the renal ostium by presence of stent wires when a feasible methodology becomes available. As mentioned earlier, VIE images were generated from the CT data acquired from a relative wide collimation (5 mm) on a single slice CT scanner, which limits image resolution in our cases. Future studies in aortic stent grafting should be performed on a multislice CT scanner as it allows thinner slice thickness and improves image quality when compared to a single slice CT.[29] It is expected that stent wires as well as 3D relationship between stent wires and the renal ostia will be better imaged on a multislice CT, including corresponding VIE images.

Conclusion

Our preliminary study demonstrated that suprarenal stent struts did not significantly affect the morphological change of the renal ostia. Stent-covered renal arteries remained patent and no renal dysfunction occurred in most of the cases following transrenal fixation, although renal ostia were crossed by stent struts to various extents. VIE images of the renal ostia and stent wires as well as their 3D relationship enhanced our understanding of the effect of transrenal fixation on the renal ostia, especially in those with ostial calcification. VIE findings will play an important role in clinical-decision making such as closely monitor patients with renal ostial calcification crossed by multiple stent wires. Further studies deserve to investigate the long-term effect of stent struts on the renal artery and renal blood flow in terms of the cross-sectional area reduction caused by stent wires and ostial calcification.

Acknowledgements

The authors would like to thank Mr John Winder for his technical assistance and Dr Peter Ellis for his clinical co-operation. Many thanks also go to Mr Mark O'Donnell for his clinical assistance in the evaluation of renal function.

References

1 Parodi JC, Blum U, Voshage G, Lammer J *et al*. Two-centre German experience with aortic endografting. *J Endovasc Surg* 1997;**4**:137–146.
2 Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. *Ann Vasc Surg* 1991;**5**:491–499.
3 Mialhe C, Amicabile C, Becquemin JP *et al*. Endovascular treatment of infrarenal abdominal aortic aneurysms by the Stentor system: preliminary results of 79 cases. *J Vasc Surg* 1997; **26**:199–209.
4 Parodi JC, Barone A, Piraino R *et al*. Endovascular treatment of abdominal aortic aneurysms: lessons learned. *J Endovasc Surg* 1997;**4**:102–110.
5 Lawrence-Brown M, Hartley D, MacSweeney ST *et al*. The Perth endoluminal bifurcated graft system: development and early experience. *Cardiovasc Surg* 1996;**4**:706–712.
6 Malina M, Lindh M, Ivancev K *et al*. The effects of endovascular aortic stents placed across the renal arteries. *Eur J Vasc Endovasc Surg* 1997;**13**:207–213.
7 Ferko A, Krajina A, Jon B *et al*. Juxtarenal aortic aneurysm: endoluminal transfemoral repair? *Eur Radiol* 1997;**7**:703–707.
8 Birch PC, Start RD, Whitebread T *et al*. The effect of crossing porcine renal artery ostia with various endovascular stents. *Eur J Vasc Endovasc Surg* 1999;**17**:185–190.
9 Alric P, Hinchliffe RJ, Picot MC *et al*. Long-term renal function following endovascular aneurysm repair with infrarenal and suprarenal aortic stent-grafts. *J Endovasc Ther* 2003;**10**:397–405.
10 Lau LL, Hakaim AG, Oldenburg WA *et al*. Effect of suprarenal versus infrarenal aortic endograft fixation on renal function and renal artery patency: a comparative study with intermediate follow-up. *J Vasc Surg* 2003;**37**:1162–1168.
11 Burks JA, Faries PL, Gravereaux EC *et al*. Endovascular repair of abdominal aortic aneurysms: stent-graft fixation across the visceral arteries. *J Vasc Surg* 2002;**35**:109–113.
12 Cayne NS, Rhee SJ, Veith FJ *et al*. Does transrenal fixation of aortic endografts impair renal function? *J Vasc Surg* 2003;**38**:639–644.
13 Desgranges P, Hutin E, Kedzia C *et al*. Aortic stents covering the renal arteries ostia: an animal study. *JVIR* 1997;**8**:77–82.
14 Lilffamn K, Lawrence-Brown MMD, Semmens JB *et al*. Suprarenal fixation: effect on blood flow of an endoluminal stent wire across an arterial orifice. *J Endovasc Ther* 2003; **10**(2):260–274.
15 Armerding MD, Rubin GD, Beaulieu CF *et al*. Aortic aneurysmal disease: assessment of stent-grafted treatment-CT versus conventional angiography. *Radiology* 2000;**215**:138–146.
16 Dorffner R, Thurnher S, Youssesfzadeh S *et al*. Spiral CT angiography in the assessment of abdominal aortic aneurysms after stent grafting: value of maximum intensity projections. *J Comput Assist Tomogr* 1997;**21**:472–477.
17 Neri E, Bonanomi C, Vignali R *et al*. Spiral CT virtual endoscopy of abdominal arteries: clinical applications. *Abdom Imaging* 2000;**25**:59–61.
18 Sun Z, Winder RJ, Kelly B *et al*. Diagnostic value of CT virtual intravascular endoscopy in aortic stent grafting. *J Endovasc Ther* 2004;**11**:13–25.
19 Winder J, Sun Z, Kelly B *et al*. Abdominal aortic aneurysm and stent graft phantom manufactured by medical rapid prototyping. *J Med Eng Technol* 2002;**26**(2):75–78.
20 Sun Z, Winder J, Kelly B *et al*. CT virtual intravascular endoscopy of abdominal aortic aneurysms treated with suprarenal endovascular stent grafting. *Abdom Imaging* 2003;**28**(4):580–587.
21 Sonesson B, Malina M, Ivancev K *et al*. Dilatation of the infrarenal aneurysm neck after endovascular exclusion of abdominal aortic aneurysm. *J Endovasc Surg* 1998;**5**:195–200.
22 Malina M, Brunkwall J, Lindblad B *et al*. Endovascular management of the juxtarenal aortic aneurysm: can uncovered stents safely cross the renal arteries? *Semin Vasc Surg* 1999;**12**:182–191.
23 Bove PG, Long GW, Zelenock GB *et al*. Transrenal fixation of aortic stent-grafts for the treatment of infrarenal aortic aneurysm disease. *J Vasc Surg* 2000;**32**:697–703.
24 Lobato AC, Quick RC, Vaughn PL *et al*. Transrenal fixation of aortic endografts: intermediate follow-up of a single-centre experience. *J Endovasc Ther* 2000;**7**:273–278.
25 Caps MT, Perissinotto C, Zierler E *et al*. Prospective study of atherosclerotic disease progression in the renal artery. *Circulation* 1998;**98**:2866–2872.
26 Caps MT, Zierler RE, Polissar NL *et al*. Risk of atrophy in kidneys with atherosclerotic renal artery stenosis. *Kidney Int* 1998; **53**:735–742.
27 von Segesser LK, Marty B, Ruchat P *et al*. Routine use of intravascular ultrasound for endovascular aneurysm repair:

angiography is not necessary. *Eur J Vasc Endovasc Surg* 2002; **23**:537–542.
28 Sun Z, Winder J, Kelly B *et al*. Assessment of VIE image quality using helical CT angiography: *in vitro* phantom study. *Comput Med Imaging Graph* 2004;**28**:3–12.
29 Hu H, He HD, Foley WD *et al*. Four multidetector-row helical CT: image quality and volume coverage speed. *Radiology* 2000; **215**:55–62.

Accepted 26 August 2004